Energy Outlook to 2035 in Asia and its Pathways Towards a Low Carbon Energy System

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1. Introduction

In Asia, energy demand has been growing rapidly under the vigorous economic growth. The annual average growth rate of its energy demand in the past 27 years (1980~2007) recorded 4.6%, it is far exceeding of the world average, 2.0%. China and India, in particular, represented very high rate of 5.5% and 6.0% respectively, which are higher than the Asian average. After the past oil crisis, energy efficiency and specifically reduction of oil demand has been pursued in the developed countries. On the contrary, in developing Asian countries, energy demand, particularly oil demand has been expanding reflecting the taking off of the industrial development combined with the urbanization and the motorization. Asian region currently shares about 30% of the world energy demand, but the per capita GDP amounts for just $3,200, which is one tenth of the OECD average, and the per capita energy demand in Asia remains one fifth of the OECD average. With the expected further economic growth, energy demand in Asia will increase further and the potential of the demand growth particularly in China and India is quite large with its huge population and expected remarkable economic growth.

This report analyzes energy demand and supply outlook in Asia and the world through 2035, based on the latest world economic trends, including the economic development of emerging countries mainly in Asia, as well as changes in the international energy situation and technological trends. In particular, the role of low-carbon technology is expected to expand even further in tackling climate change and securing stable energy supply. Thus, in addition to the “Reference Scenario” which considers past trends and incorporates current energy and environment policies, this paper provides “Technologically Advanced Scenario” where advanced low-carbon technology becomes even more widespread around the world on the back of the promotion of international technology transfers mainly from developed countries to developing countries. The second section describes modeling framework and the key exogenous assumptions. The third section identifies the reference energy projections in the world and Asia together with CO_2 emissions. The fourth section outlines the evaluation of future energy demand and supply in Technologically Advanced Scenario. Finally, the paper concludes with the key implications of this outlook.

2. Socio-economic trends to 2035

Energy modeling framework for our projection is formulated with econometric method in a country-by-country basis, combined with other end-use energy model [1]. Concerning regional breakdown, entire world is disaggregated into 30 countries or region. Particularly, Asian region is composed of 14 countries or regions, namely, China, Japan, Hong Kong, Taiwan, Korea, Singapore, Brunei, Indonesia, Malaysia, Philippines, Thailand, Vietnam, India, Other Asia , in order to implement more profound analysis of Asia than a couple of other world energy projections [2][3].

For the energy projection, exogenous assumptions regarding socio-economic trends, such as economic growth, population and energy prices, are likely to play an influential role in our analysis.

2.1 World economic growth and population to 2035

Figure1 displays average annual growth rate of GDP and population assumed in this analysis. Estimation of GDP growth rate is basically derived from the IMF estimation [4], the Asian development bank [5] and each governmental outlook for medium to long-term.

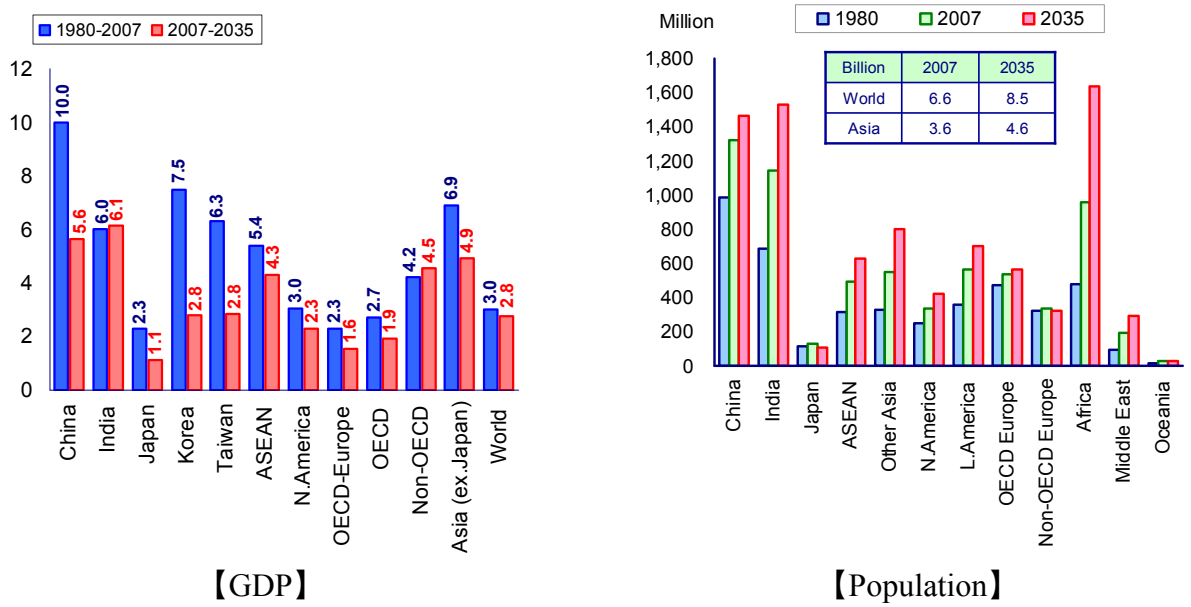


Figure1: GDP growth rate and population to 2035.

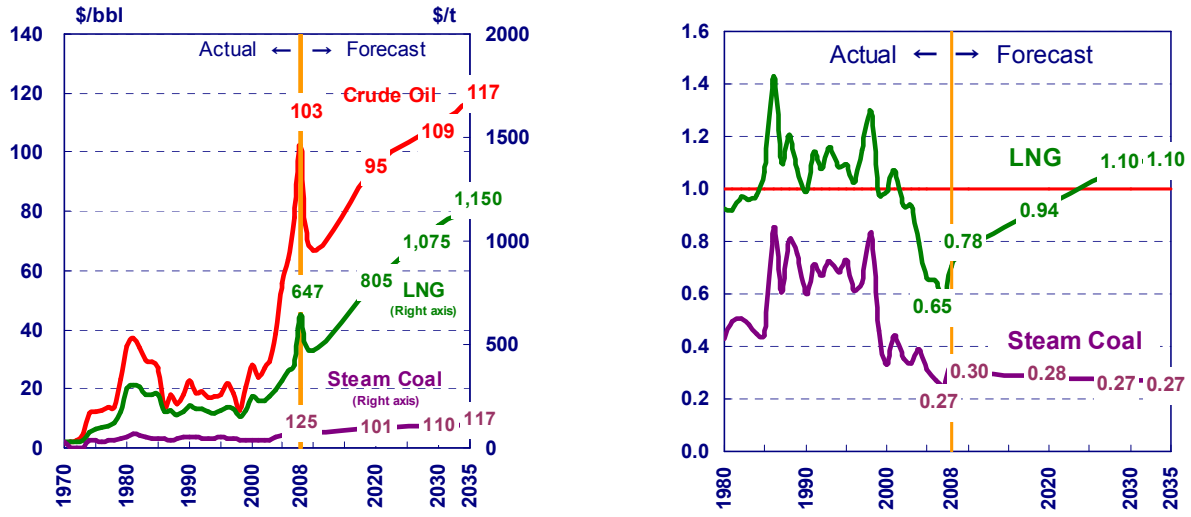
Driven mainly by growing Asian economy, the world economy is expected to represent moderate growth rate of 2.8% per annum from 2007 to 2035. By region, North America and OECD Europe are projected to show stable economic growth at 2.3% and 1.6% respectively. In Asia excluding Japan, the forecast is sustained remarkable growth of 4.9%, due to the presence of economies with enormous markets such as China, India, and ASEAN countries. China will shift its leading driver of economic growth from investments and exports to domestic consumption. Although it has a number of problems such as internal income disparities, China would be able to achieve high-order growth averaging 5.6% annually through 2035, provided that it continues to do proper macroeconomic management. GDP in India assumes high growth 6.1% reflecting on improving economic efficiency by liberalization and direct investment from foreign countries, and industrialization through IT-based service industry. Japan's economic growth shows lower growth at 1.1% due to population decreasing, aging and diminishing marginal productivity of capital.

Regarding the prospect of population, the world population will grow from 6.6 billion in 2007 to 8.5 billion in 2035, although birthrates will show downward trend in developing countries as its increase in economic development. Population prediction is derived from UN forecast [6]. Within Asia, the population will expand to 1.46 billion in China and 1.53 billion in India by 2035. The population of the entire Asian region, as the most populous region in the world, will increase to 4.5 billion in 2035, accounting for 53% of the world total population, from 3.6 billion in 2007.

2.2 Energy prices to 2035

Figure2 illustrates future energy price adopted in this energy projection and relative LNG and coal prices to crude oil prices in terms of the Japanese import price on a C.I.F. basis. Crude oil prices are predicted in ranges, and are estimated to move in the range of around $90/barrel to

$110/barrel in 2020 and around $110/barrel to $130/barrel in 2035. A roughly intermediate value of the range is used for the analysis. After around 2010, a production shift from the large oil fields to the small and medium sized oil fields or the deep water oil fields with relatively high production cost is expected. Reflecting this physical shift of oil production, crude oil price will go up gradually. The future trend for crude oil prices is prepared on the basis of the price estimation such as the Annual Energy Outlook released by the EIA/DOE [7].



【Japan's import energy prices, CIF base】 【Relative Prices to Crude Oil】

Figure2: Japan's import energy prices on a CIF basis to 2035.

LNG price will go up linking with the crude oil price. Coal price has been fluctuated but in a very small range compared with those of crude oil and LNG. In the recent past, however, coal price also went up due to the short term demand and supply imbalance resulted from the expanded demand but the range of its price will remain small since the resource constraint of coal is small relative to crude oil and natural gas. Location of coal resource is diverse over the world and a large amount of coal has been supplied from the politically stable areas.

In terms of relative price, LNG price is currently cheaper compared with crude oil price. For the long-term trend, the price gap between crude oil and LNG will become smaller. By 2035, LNG price will slightly outstrip that of crude oil, and price of LNG relative to that of crude oil will move to 1.1, reflecting on the possible change of LNG price formula and environmental premium of natural gas. Coal relative price will remain roughly constant for 2035.

3 Energy projection in Reference Scenario

3.1 Primary energy consumption by region

Figure3 illustrates the world primary energy demand by region and regional share over the world. To 2035, the world primary energy demand is anticipated to increase at an average annual growth rate of 1.5% under annual GDP growth of 2.8%. GDP elasticity is calculated as 0.5 from 2007 to 2035, while around 0.7 from 1980 to 2007. The world demand in 2035 is expected to reach 16.9 billion ton of oil equivalent (btoe), a 1.5-fold increase from 11.1 btoe in 2007.

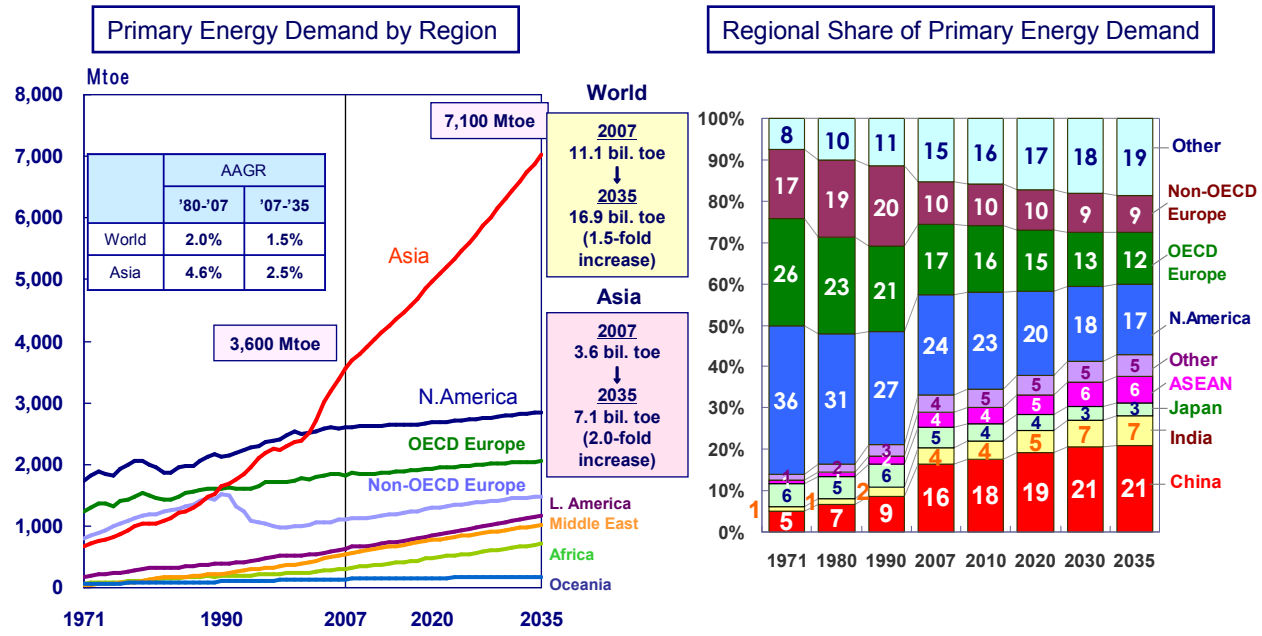


Figure3: World primary energy demand to 2035 by region.

Primary energy demand in Asia is projected to grow at 2.5% per annum and reach 7.1 btoe in 2035, for a 2.0-fold increase from 3.6 btoe in 2007. Asia would account for approximately 61% of the world primary energy increase to 2035, reflecting its sharp economic growth, and the share of Asia in world primary energy demand is likely to rise from 33% in 2007 to 42% in 2035.

Significant growth is expected particularly in countries achieving fast-paced economic growth, such as China, India, Vietnam, Thailand, Malaysia, Indonesia and other ASEAN countries. Primary energy consumption in China is projected to increase at an average annual rate of 2.4%, and would amount to 3.5 btoe by 2035, almost twice as much as 1.8 btoe in 2007. Primary energy demand in India will increase sharply at 3.7% per annum, and would reach 1.2 btoe, around 2.8 times more than 0.4 btoe in 2007. China alone accounts for 29% of the incremental increase in the world primary energy demand to 2035, which surging is the biggest on a country basis. India also explains 13% of the world primary energy increase. The share of China in the world primary energy demand is forecast to increase from 16% in 2007 to 21% in 2035, and the share of India, from 4% to 7%. However, energy consumption per capita in China and India in 2035, each 2.4 toe and 0.8 toe per capita, remains well under the level of developed countries, for instance, 4.8 toe per capita in OECD average at 2035. Therefore, both China and India have large potential of energy demand expansion even after 2035 and its presence in the global energy market would become even larger.

Figure4 shows primary energy demand by fuel in both the world and Asia, and Figure5 displays its incremental increase in primary energy demand. Fossil fuels are expected to contribute about 80% of the increase in primary energy consumption to 2035 in both Asia and the world, and therefore would continue to play an important role. In the world, natural gas demand is predicted to show the largest increase of all fossil fuels and account for 34% of the increase in primary energy consumption, followed by oil at 23%, and coal at 22%. In the world, oil will remain the single largest fuel whereas natural gas will overtake coal as the world's second-largest energy source around 2035. Meanwhile in Asia, coal demand is predicted to show the largest increase of all fossil fuels and account for 33% of the increase in primary energy demand, followed by oil at 27%, and natural gas at 22%. In Asia, coal and oil will play a central role in primary energy supply, while gas,

nuclear and renewables gradually diversify supply sources to 2035.

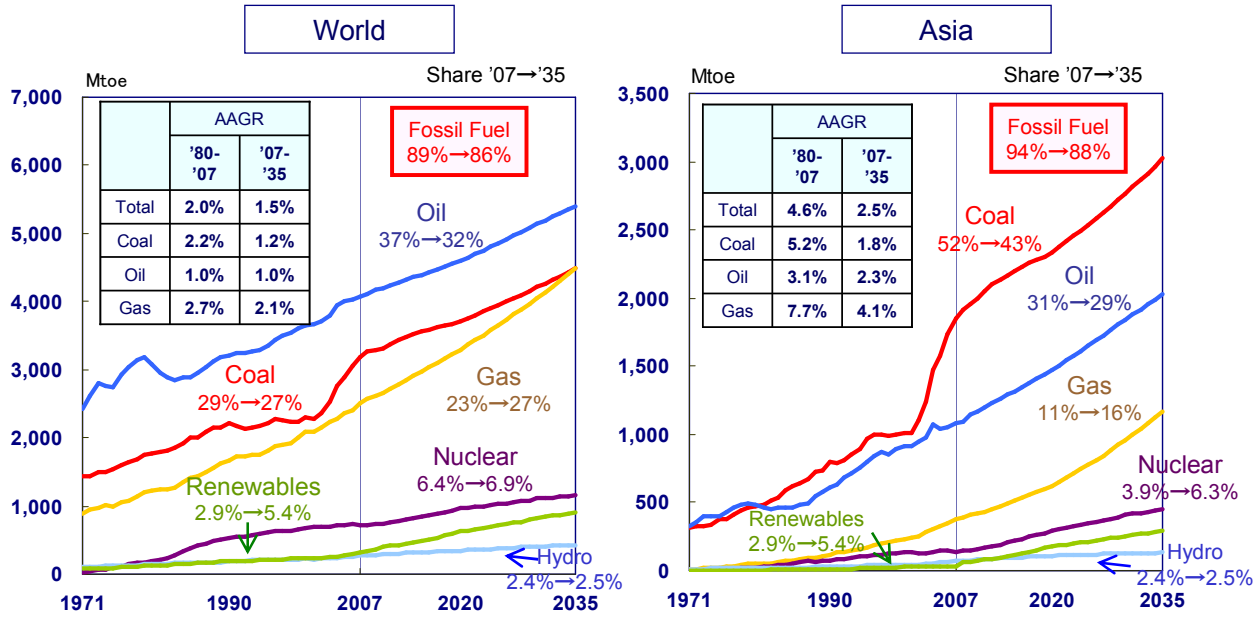


Figure4: Primary energy demand in the world and Asia to 2035 by energy source.

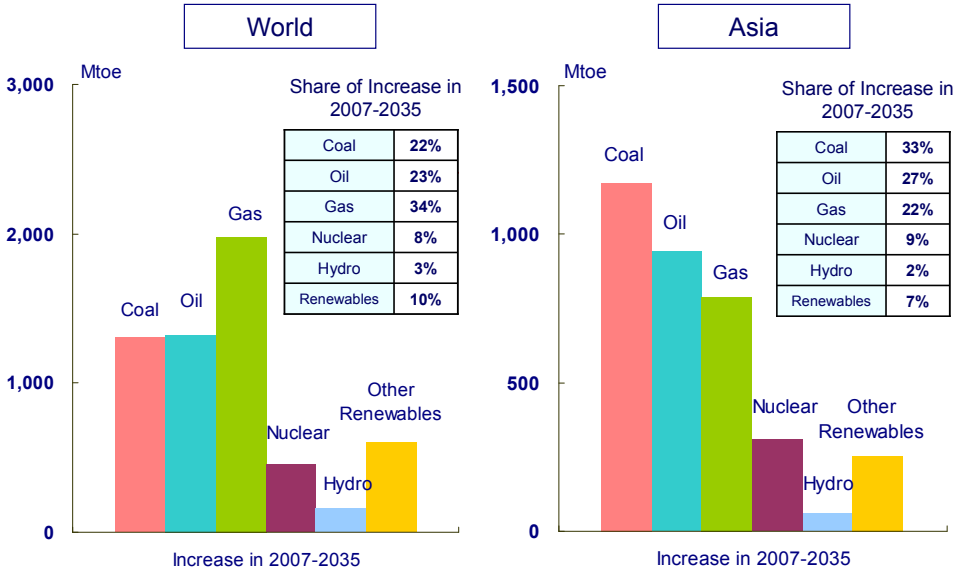


Figure5: Incremental increase in primary energy demand by fuel from 2007 to 2035.

Oil demand in the world is projected to increase at an average annual growth rate of 1.0%, with its share in primary energy demand forecast to decline slightly, from 37% in 2007 to 32% by 2035, but oil would nevertheless remain the single-largest energy source. By sector, it is estimated that more than 60% of oil demand increase will come from transport sector in both world and Asia, as illustrated in Figure6. World natural gas demand is forecast to increase at an average annual rate of 2.1%, the highest among the fossil fuels. By sector, 57% of the increase in natural gas consumption would derive from the fuel input into the power sector, where the installation of combined-cycle power generation steadily proceeds due to its technological advances and environmental considerations. Expanded utilization in this sector is expected to drive an increase in

the natural gas share of world primary energy demand, from 23% in 2007 to 27% by 2035. World coal demand is projected to grow at 1.2% per annum, with its share of primary energy demand will slightly decline from 29% to 27%. By sector, more than 90% of coal increase is projected to come from the power sector in both world and Asia. Nuclear in the world is forecast to rise at an average annual growth rate of 0.7%. The nuclear share of primary energy is expected to increase from 6.4% to 6.9%. The increase in nuclear would be mainly attributable to Asian countries such as China, India, Japan and Korea. The share of renewable excluding hydro in the world will increase substantially from 2.9% to 5.4% owing to the progress in cost competitiveness of, for instance, photovoltaic and wind power.

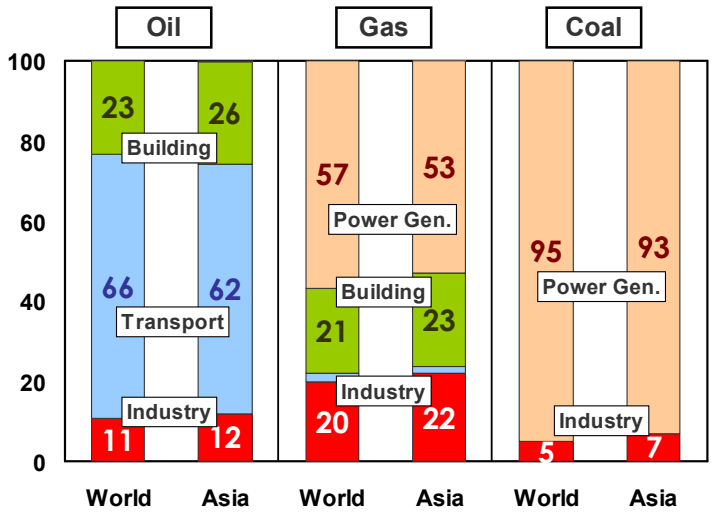


Figure6: The share of incremental increase in fossil fuel demand by sector.

Figure7 illustrates power generation mix by energy source in both world and Asia. In the world, the share of primary fuel input for power generation in total primary energy demand will grow from 39% in 2007 to 44% in 2035, reflecting that electricity demand will show remarkable growth and expand its share in almost all end-use sectors. Hence, for 2035, primary energy consumption will be concentrated on power sector and efficient use of energy source in this sector is considered to be quite important challenge in terms of dealing with climate change and energy security issues. Since electrification accelerates particularly in Asia along with improvements in income levels and progress in urbanization, electricity consumption will grow 2.5-fold over the forecast period. Electricity demand in Asia increased at annually 6.4% from 1980 to 2007, and is forecast to increase at 3.3% per annum from 5,530 TWh in 2007 to 13,830 TWh in 2035. By sector, the rate of increase is expected to be the highest in the residential and commercial sector at 4.8%. By region, China will have vigorous increasing rate at 3.2% from 2,680 TWh to 6,400 TWh, and India, at 5.7% from 570 TWh to 2,700TWh to 2035.

Since the share of Asia in world electricity demand will boost from 34% in 2007 to 44% in 2035, the future configuration of power generation mix in Asia is regarded as being influential factor in considering future global energy market and climate change. At 2007 in Asia, coal-fired power accounted for the single-largest share at 60%, followed by natural-gas-fired power, hydropower, and nuclear power.

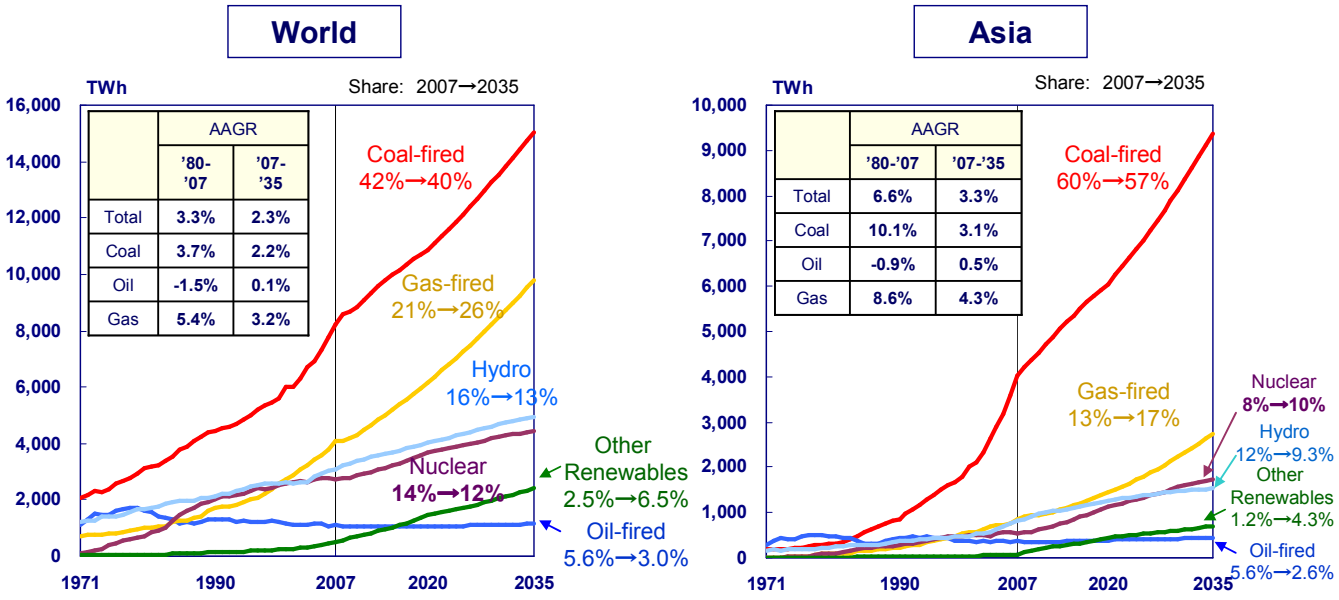


Figure7: Electric power generation to 2035 in the world and Asia.

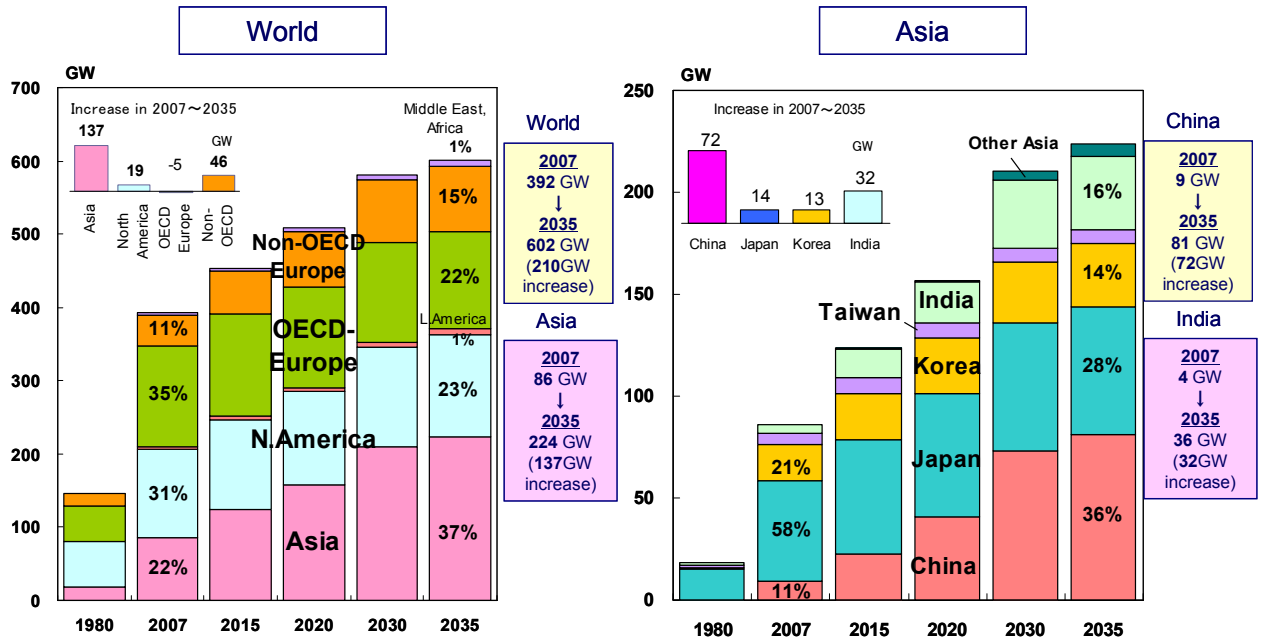


Figure8: Nuclear power capacity in the world and Asia.

The outlook of power generation mix in Asia envisages a shift to natural-gas-fired plant along with the spread of combined-cycle gas turbine and efforts to alleviate environmental burden. The share of natural-gas-fired power is forecast to increase from 13% in 2007 to 17% by 2035. Since the share of coal-fired generation in Asia is projected to hold 57% even as of 2035, it would remain the single-largest power supply source, based on regional abundant resource endowment, its economic affordability, and in accordance with the policy for effective coal use in order to conserve domestic oil and gas reserves in energy producing countries. Nuclear will rise at an average annual growth rate of 4.3%. The nuclear share of power generation mix in Asia is expected to increase from 8% to 10% owing to the fast-paced expansion of electricity demand particularly in China and India. Nuclear power will also continue to play a vital role in Japan, South Korea, and Taiwan, which have

few domestic energy reserves. In addition, Vietnam and other ASEAN nations are likely to newly install nuclear power plant in forecast period. As depicted in Figure8, nuclear capacity of Asia is projected to expand from 86GW in 2007 to 224GW in 2035, achieving 137 GW growth which accounts for 65% of world nuclear increase.

Concerning renewable energy, these are expected to expand due to technological advancement and supportive political measures such as FIT and subsidization. World's photovoltaic power generation capacity will grow sharply from 15 GW in 2008 to 242 GW in 2035, a 16-fold increase, and world's wind power generation capacity will boost from 121 GW in 2008 to 602 GW in 2035, a five-fold increase. Photovoltaic and wind power generation together accounted for 0.9% of the world's total power generation in 2007 and will grow for 3.6% in 2035. Thus, PV and wind power will still not become major power sources by 2035 in the world.

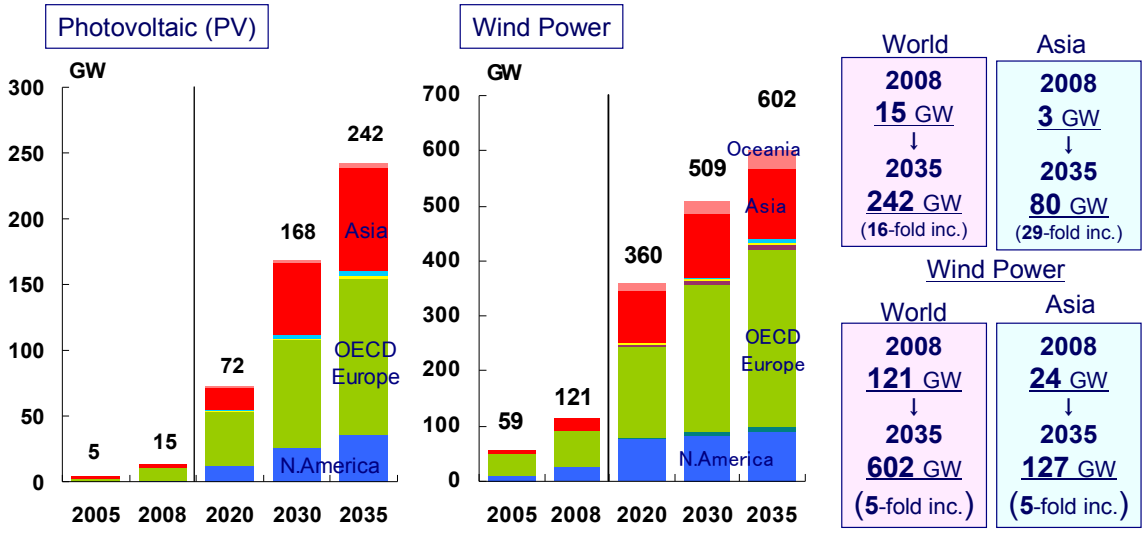


Figure9: PV and wind power capacity in the world and Asia.

China

Figure10 shows the outlook of primary energy demand in China and India to 2035. Primary energy consumption in China will increase at a rate of 2.4% per annum, from 1.77 Btoe in 2007 to 3.45 Btoe, accounting for 21% of the world consumption, in 2035. By energy source, the share of coal in primary energy demand declines from 73% in 2007 to 53% by 2035, from 39% to 18% in final energy demand, and from 81% to 70% in power generation mix. The reduction of coal dependence is derived principally from improved efficiency in coal-fired power plant, fuel diversification in power generation mix and future sluggish growth of steel production. Average conversion efficiency of coal-fired plant will move upward to 41% in 2035 from 33% in 2007, and Iron and steel production, which came to 501 million tons in 2008, will peak in the near future and decline to just under 400 million tons through 2035, so that industrial coal consumption will subsequently go down. In primary energy demand, instead, the share of natural gas will grow from 3.3% in 2007 to 9.6% by 2035 due to fuel switching mainly in power generation sector and that of oil from 20% to 26% reflecting on motorization. Growing proportion of electricity consumption in final energy demand from 22% in 2007 to 25% by 2035, reflecting rapid industrialization and urbanization, will contribute to decrease coal dependence as well.

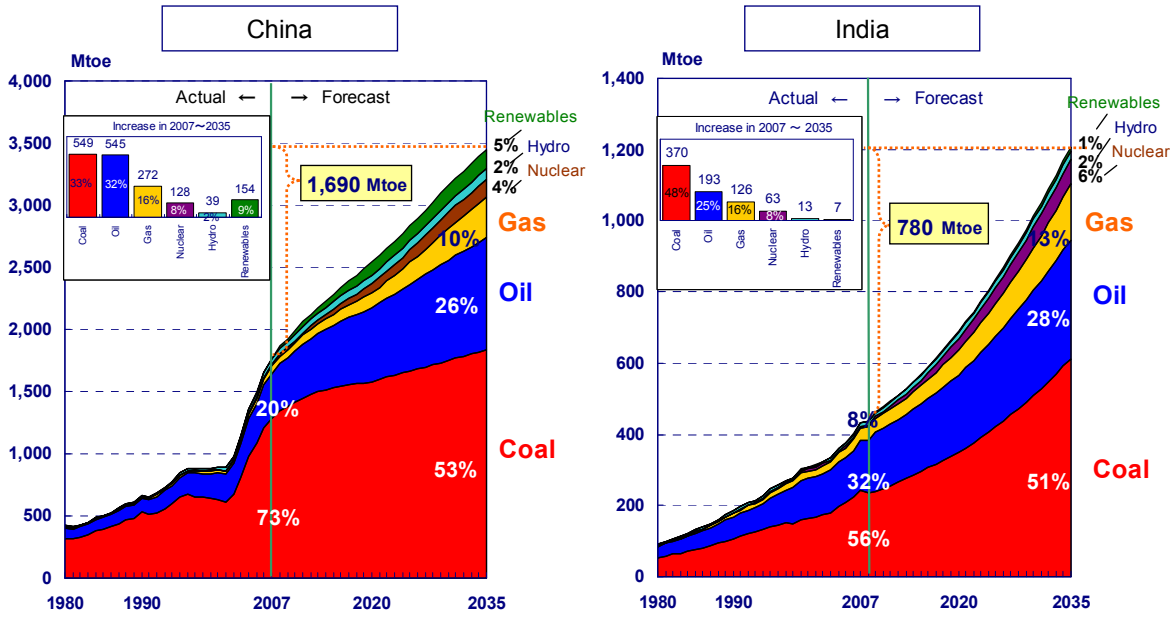


Figure10: Primary energy consumption in China and India to 2035.

Oil demand in China will expand from 7.4 million b/d in 2007 to 18.8 million b/d in 2035 due to fast progress in motorization. Chinese automobile ownership will strongly grow from 42 million in 2007 to 296 million in 2035. Domestic oil production fails to increase and go down to 3.7 mb/d by 2035 from 3.9 mb/d in 2007, though it will be maintained by raising the recovery rate in the operating oil fields and promoting development of new oil fields. Therefore, Chinese dependence on imports for oil supply will rise from 48% in 2007 to 79% in 2035 and the self sufficiency of oil in China will fall further.

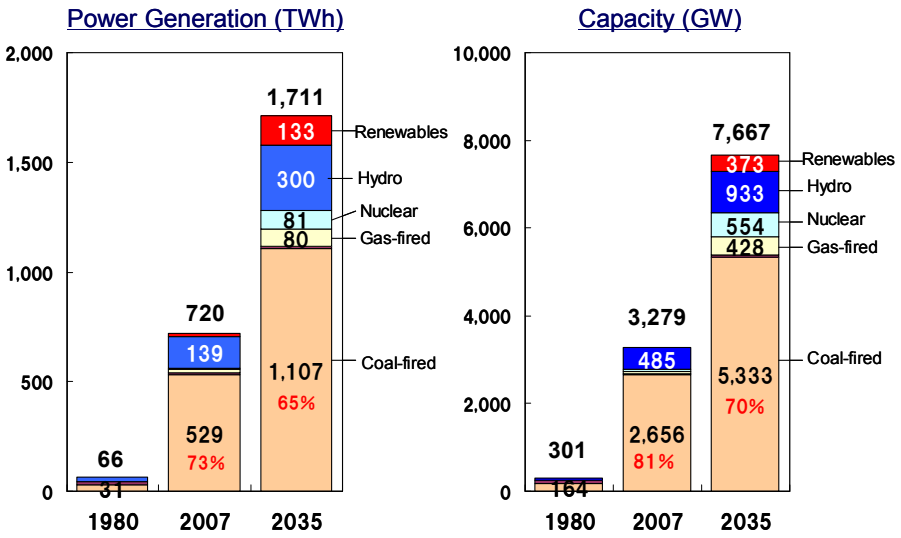


Figure11: Power generation mix in China to 2035.

In power generation sector of China, gas and nuclear are projected as main sources to replace coal, although coal-fired power plants will remain the single largest power supply source through 2035 as shown in Figure11. The capacity of nuclear power plant in China will increase from 9GW in 2007 to 81GW in 2035. Although renewables in primary energy total is projected to increase

sharply under the assumption that wind power capacity will boost from 12GW in 2007 to 80GW in 2035, the share in primary energy will still remain only 4.6% in 2035. The modernization of energy demand and supply would gradually induce fuel switching mainly from coal.

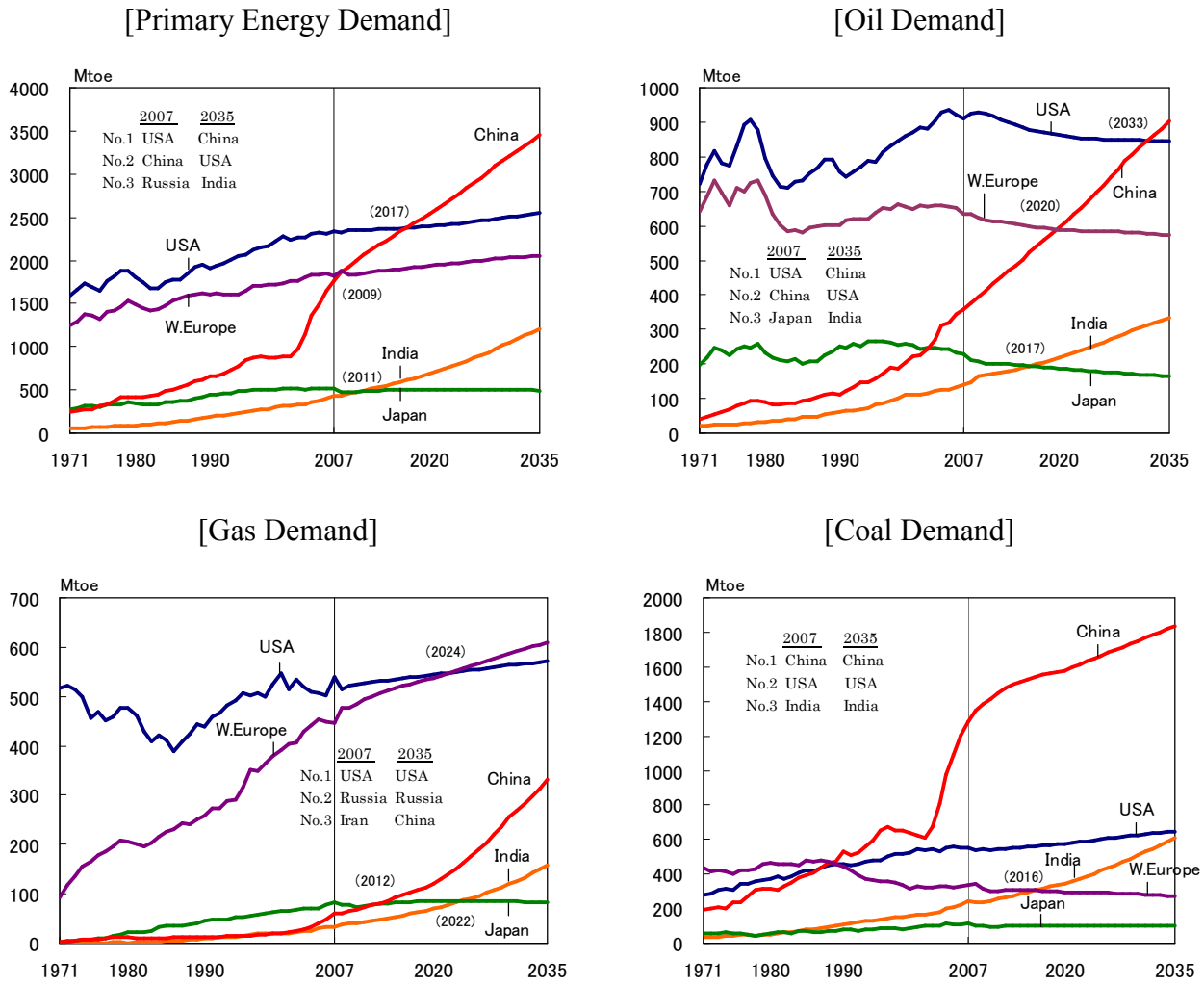


Figure12: Primary energy demand in selected region to 2035.

Figure12 explains primary energy demand by selected region or country focusing on China. China will become the largest energy-consuming country by 2017 in primary energy demand and by 2033 in primary oil demand. In natural gas, China is forecast to rank as the third largest consumer by 2035, outstripping Japan by 2012. Concerning coal demand, China will continue to be the single largest consuming country through 2035.

India

India's population will reach 1.5 billion in 2035, larger than China and become the largest populous country in the world. It is characteristic that the share of the younger generation is large in the demographic structure. Population in the urban area will increase but the population in the rural area will continue to share more than half. Regarding economic growth, India realized stable economic growth in the recent years through expansion in the service sector. Service sector and the expansion of the industrial production are likely to lead the future economic growth. The Indian economy will grow steadily at a rate of 6.1% per annum. Primary energy demand expanded by

more than 4 times in the past 27 years from 91 Mtoe in 1980 to 433 Mtoe in 2007. It will grow by nearly 3 times towards 2035 and will reach 1,208 Mtoe. India will become the third largest energy consuming country in the world after China and USA by 2035. The share of India in the world primary energy demand will rise from 4% in 2007 to 7% in 2035. By energy source, coal will keep the current position as the main energy source but its share will decline gradually and the share of natural gas and oil will replace the coal's share. Nuclear and other energy sources will increase but 90% of the incremental energy consumption will be covered by fossil fuel. While oil consumption will increase and domestic oil production will decline, oil import will eventually grow. Oil demand will increase from 2.9 million b/d in 2007 to 7.0 million b/d in 2035. As a large increase in domestic oil production cannot be expected, India's dependence on imports for oil supply will rise sharply from 69% in 2007 to 86% in 2035.

3.2 Outlook for CO_2 emissions

Figure13 shows the future trajectory of CO_2 emissions to 2035 in the world and Asia. Since fossil fuels would be responsible for about 80% of the incremental increase in world primary energy consumption through 2035, global CO_2 emissions, which came to about 28.8 billion tons (carbon dioxide-equivalent) in 2007, are forecast to reach about 41.5 billion tons by 2035.

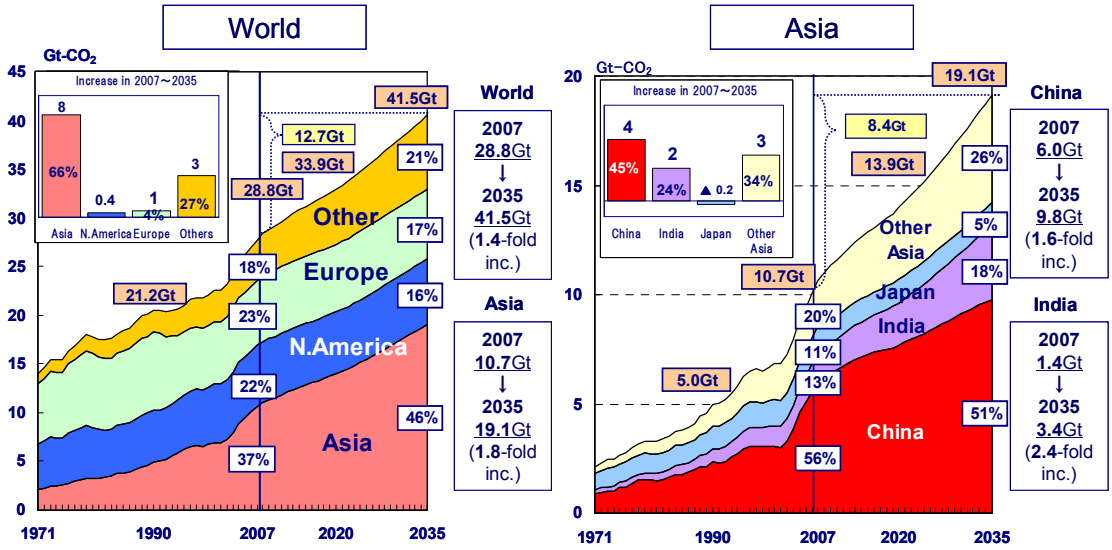


Figure13: CO_2 emissions in the world and Asia to 2035.

World CO_2 emissions will expand at an average annual rate of 1.5%, about the same as for primary energy consumption, and exhibit a 1.4-fold increase to 2035. China and the whole Asian region will be responsible for about 30% and 60% respectively of the world incremental growth of CO_2 emissions, which implies that Asian region will lead the global growth of CO_2 emissions.

4 Energy projection in Technologically Advanced Scenario

4.1 Conceptual framework and major assumption

Technologically Advanced Scenario (Tech. Adv. Scenario) analyses how the global energy demand and supply could evolve if countries were to adopt all of the policies they are currently considering related to energy security, CO_2 emissions and technology transfer, and advanced technology widely deployed all over the world. The aim of this analysis is to understand how far

those policies and technological development could take us in dealing with energy and environmental challenges. Many of the policies considered in the Technologically Advanced Scenario lead to faster deployment of more efficient and less polluting technologies. As those technologies are deployed under the stimulus of national policy, the unit cost of the technology falls, so that it subsequently becomes available globally at a lower cost than in the Reference Scenario. As a result, cleaner technologies are deployed sooner and more widely than in the Reference Scenario. This approach allows us to give an indication of the potential energy and CO_2 savings achievable with incremental improvements and introduction in existing and advanced technologies which might reasonably be expected to be deployed by 2035. In general, the rate of improvement in energy efficiency in the Technologically Advanced Scenario is higher in developing countries, particularly in Asia, than in developed countries. This reflects the larger potential for efficiency improvements in those regions and the fact that additions to the physical capital stock are expected to be much larger in developing countries than in the OECD.

Table1: Energy technology considered in Technologically Advanced Scenario.

Regulation, National target, SSL etc.	Promotion of R&D, International Cooperation
Carbon tax, Emissions Trading, RPS, Subsidization、FIT、Efficiency Standard, Automobile Fuel Efficiency Standard, Low Carbon Fuel Standard, Energy Efficiency Labeling, National Target etc.	Encouragement of Investment for R&D, International Cooperation on Energy Efficient Technology, Support on Establishment of Efficiency Standard

【Demand Side Technology】	【Supply Side Technology】
■ Industry Best available technology on industrial process such as steel making, cement, paper, oil refinery etc. become internationally penetrated ■ Transport Clean energy vehicles (high fuel efficient vehicle, Hybrid vehicle, Plug-in hybrid vehicle, Electric vehicle, Fuel cell vehicle) globally expand. ■ Building Efficient electric appliance (Refrigerator, TV etc.), High efficient water-heating system (heat-pump etc.), Efficient air conditioning system, Efficient lighting, Strengthening heating insulation	■ Renewable More expansion of Wind, PV, CSP, Biomass power generation, Bio-fuel ■ Nuclear Acceleration of more nuclear power plant, Enhancement of operating ratio ■ High Efficient Fossil-fired Power Plant More expansion of Coal-fired power plant (USC, IGCC, IGFC), Natural gas MACC ■ CCS Introduction in power generation (coal-fired, gas-fired) and industrial sector

A number of technologies and assumed policy are listed in Table1. The efficiency of supply-side technologies is assumed to improve more quickly in the Technologically Advanced Scenario. For example, the faster deployment of biofuels is expected to bring down their production cost more quickly and the more number of hybrid vehicles are likely to be on the road than in the Reference Scenario. In the power sector, renewables-based technologies are assumed to be deployed more widely, and the efficiency of thermal plants is assumed to increase. The basic assumptions about economic growth and population are the same as in the Reference Scenario. Although there may be some feedback from the new policies to economic performance in practice, this factor was considered too complex and uncertain to modeling.

Figure14, for example, describes breakdown of automobile ownership and annual sales in the world. Reflecting on the strong consciousness for addressing climate change and tackling international energy security issues, large expectation has grown about the global deployment of clean energy vehicle which provides the dramatic improvement of fuel efficiency, fuel diversification and massive mitigation of CO_2 emissions.

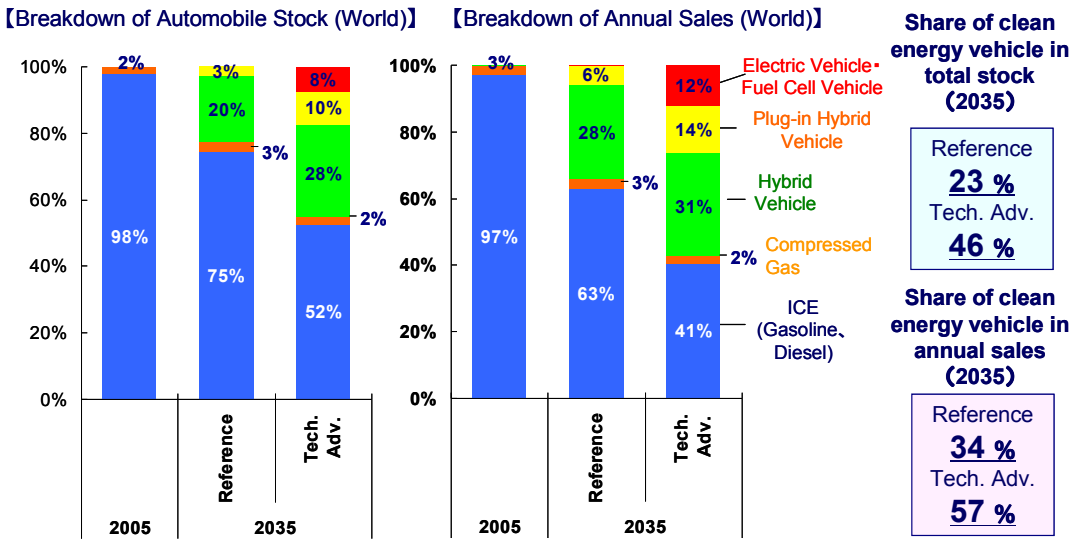


Figure14: Breakdown of automobile ownership and annual sales in the world.

Achieving the additional efficiency improvements assumed in the Technologically Advanced Scenario requires improvements in the efficiency of internal combustion engines (ICE), and a higher penetration rate of advanced vehicle technologies like plug-in hybrid and electric vehicle. In the Reference Scenario, conventional type of vehicle, such as internal combustion engine, shares more than 70% of world automobile holding in 2035 and dominates the global automobile ownership through forecast period. By contrast, in the Technologically Advanced Scenario, approximately 50% of world total stock in 2035 is composed of clean energy vehicle like plug-in hybrid vehicle, electric vehicle and fuel cell vehicle. Sales of clean energy vehicles would make up around 60% of new light-duty vehicles sales in the Technologically Advanced Scenario. In the Reference Scenario, fuel efficiency of world passenger vehicle on a stock basis will improve from 9 km/L in 2005 to 12 km/L in 2035. Reflecting on extensive deployment of advanced vehicle in the Technologically Advanced Scenario, the fuel efficiency in 2035 becomes improved to 16 km/L, which is improved by 31% compared with the Reference Scenario. Those measures combined would avoid the combustion of 11 mb/d of oil in the world and 5 mb/d in Asia by 2035.

Figure15 describes power generation mix of world and Asia in the Reference and Technologically Advanced Scenario. The policies under consideration that affect the power sector are mainly driven by concern to increase the use of low-carbon technologies or to reduce dependence on imported fuels. The most important policies and measures considered in the Technologically Advanced Scenario include: Incentives and regulations to boost the use of renewables, Programmes to improve the efficiency and reduce the cost of advanced technologies in power generation, Policies to increase the use of nuclear power. These policies eventually lead to the dramatic reduction of carbon intensity on power generation. In the Reference Scenario, the world power sector relies increasingly on fossil fuels: about 70% of electricity generation is based on fossil fuels in 2035. Coal and gas-fired plants make up nearly three-quarters of the additional electricity generation. In the Technologically Advanced Scenario, the share of fossil fuels in world electricity generation mix falls to 56% by 2035 from 68% in 2007. The largest fall is in the share of coal, which drops to 29% in 2035 from 42% in 2007 – the share at 2035 in the Reference Scenario is 40%. The change in the electricity mix is more pronounced towards the end of the projection period, reflecting the rate of capital stock turnover, the long lead times for power plants,

improvements in technology and reductions in the capital costs of new technologies. Power generation efficiency of coal-fired power plant in the world average, for instance, will exhibit incremental increase from 34% in 2007 to 45% by 2035 in the Technologically Advanced Scenario, 4% points up from the value in the Reference, 41% in 2035. Considerable improvement in Technologically Advanced Scenario fully considers the massive deployment of clean coal technology such as ultra super critical coal fired-power generation, IGCC and IGFC.

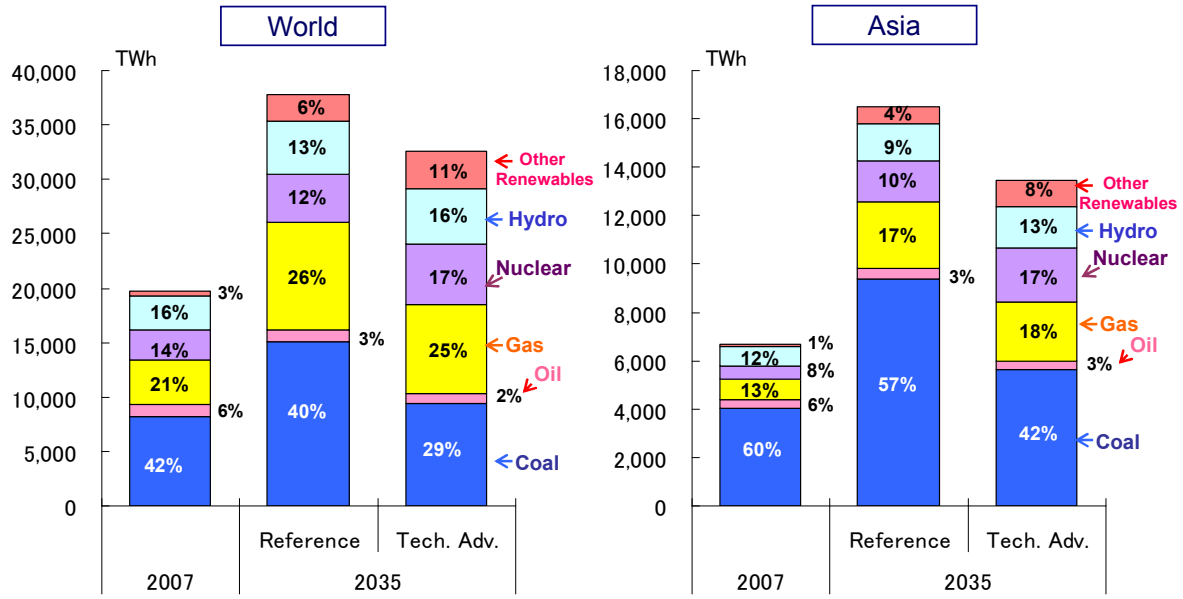


Figure15: Power generation mix in the world and Asia.

Due to technological progress and associated cost reduction, further renewable energy deployment is also expected in the Technologically Advanced Scenario. PV capacity of the world will grow from 15 GW in 2008 to 242 GW in the Reference and 590 GW in the Technologically Advanced Scenario by 2035. Concerning global wind power, its capacity will expand from 121 GW in 2008 to 602 GW in the Reference and 740 GW in the Technologically Advanced Scenario by 2035. As a result, the share of PV and wind power generation together in global power generation mix in 2035 will edge up from 4% in the Reference to 7% in the Technologically Advanced Scenario. World nuclear power capacity will increase from 392 GW in 2007 to 602 GW in the Reference and 750 GW in Technologically Advanced Scenario by 2035 and its share in global power generation mix in 2035 will grow to 12% in the Reference and 17% in the Technologically Advanced Scenario. This is because fewer nuclear power plants are shut down over the period 2007-2035 and because more new nuclear power plants are built.

4.2 Primary energy demand in Technologically Advanced Scenario

Figure16 illustrates aggregate primary energy demand of the world and Asia. In the Technologically Advanced Scenario, primary energy demand in the world at 2035 is expected to achieve 14,572 Mtoe, 2,305 Mtoe or 14% less than in the Reference Scenario. The amount of saved energy in 2035 is roughly equal to 4 times of total primary energy demand currently in Japan. Energy demand is projected to grow by 1.0% per year, 0.5 percentage points less than in the Reference Scenario. Of the world total energy savings, OECD countries will account for about 700 Mtoe and Non-OECD countries 1,600 Mtoe. Thus, energy savings potential in Non-OECD will be

more than double those in OECD countries. Primary energy demand in Asia at 2035 will be 1,338 Mtoe or 19% less than in the Reference. The magnitude of energy savings is approximately twice as much as Japan's total energy demand. Asian energy-saving potential is extremely high, with its 1,338 Mtoe in energy savings accounting for about 58% of the world total savings.

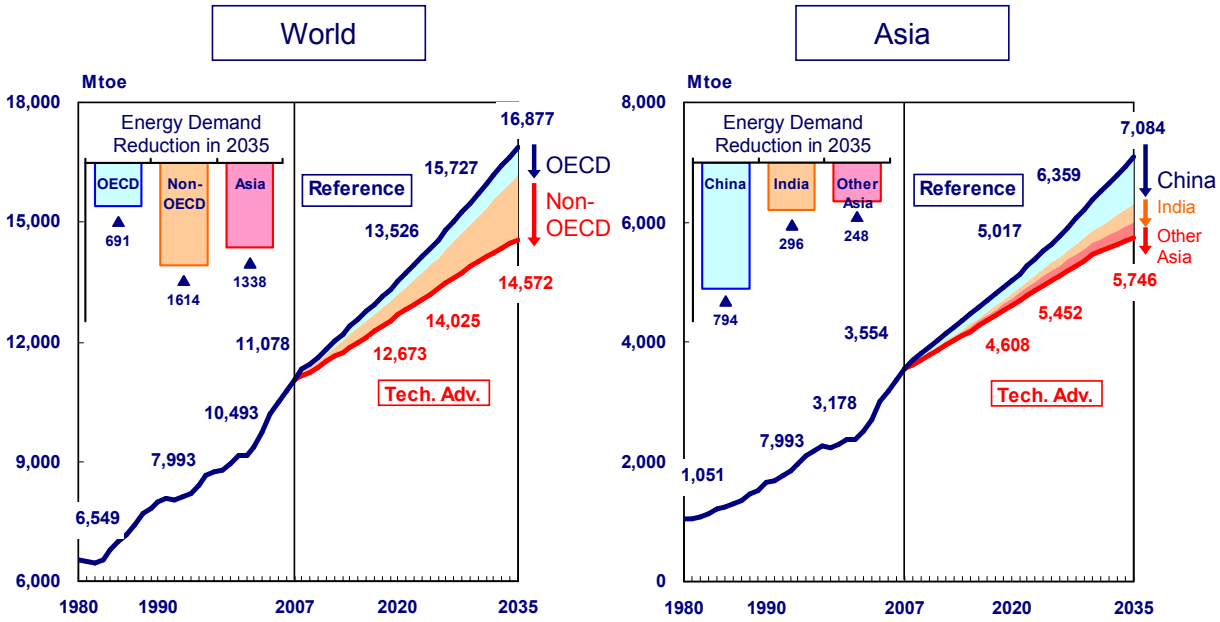


Figure16: Primary energy demand in the world and Asia.

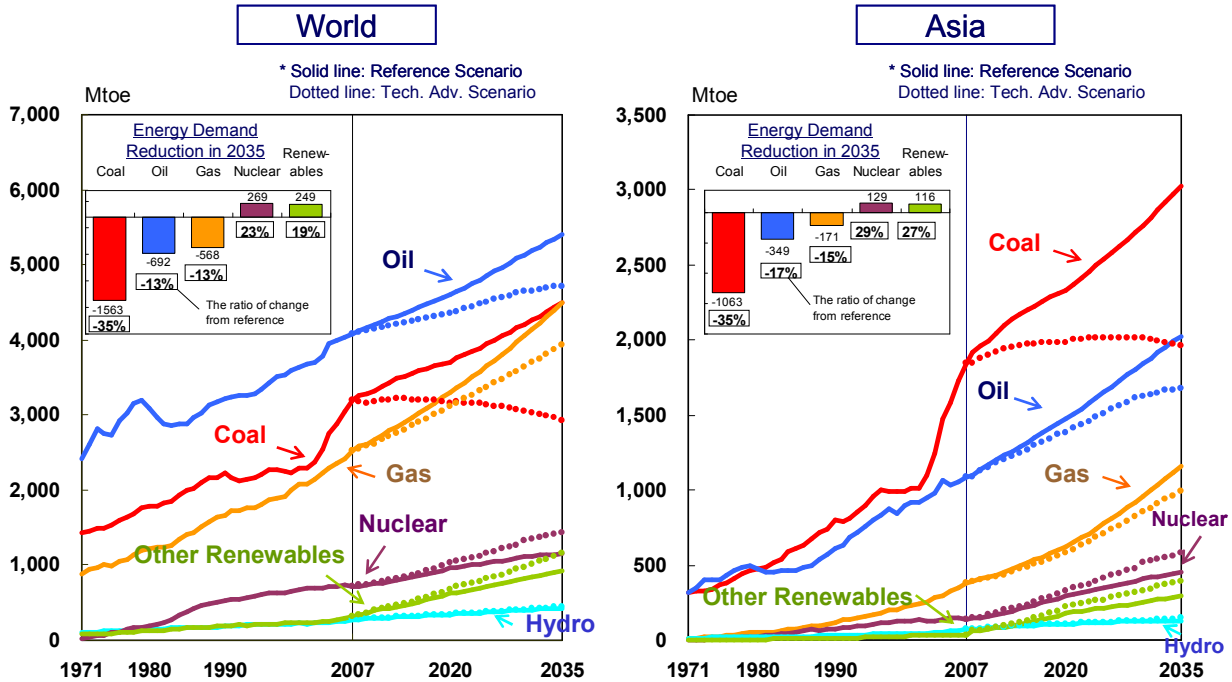


Figure17: Primary energy demand by energy source in the world and Asia.

Figure17 shows primary energy demand by energy source in the Reference and the Technologically Advanced Scenario. The reduction in demand for fossil fuels is even bigger, due to the use of more efficient technology and switching to less carbon-intensive fuels. Globally, in

Technologically Advanced Scenario, demand for fossil fuels is 2,823 Mtoe, or 20% lower in 2035. By contrast, non-hydro renewable supply increases. The use of non-fossil energy is expected to increase by the following percentages: 23% for nuclear power and 19% for renewables. The impact of energy efficiency policies on energy demand deepens throughout the forecast period, as the stock of energy capital is gradually replaced. Coal demand declines most significantly in the Technologically Advanced Scenario. The saving is bigger than for any other fuel, both in the world and Asia, and particularly Asia will explain about 70% of coal demand reduction in the world. Most of the saving in primary coal demand is derived from power generation in Asia. Coal use in that sector is driven down by electricity demand savings, by the improved thermal efficiency of coal-fired power plants – especially in China and India – and by switching to other fuels. Promoting clean coal technology in Asia has tremendous significance in order to ensure coal supply and environmental protection.

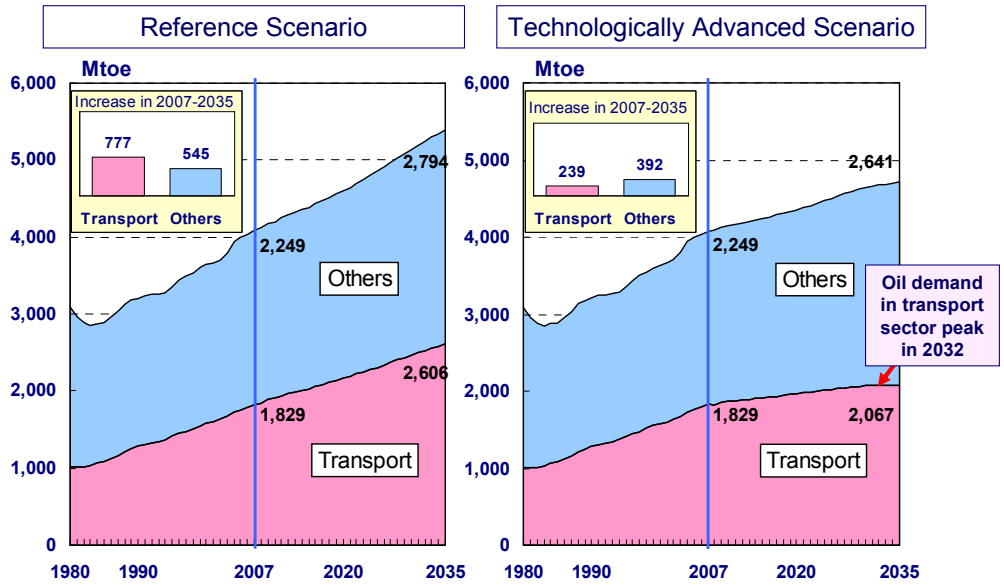


Figure18: Global oil demand in Reference and Technologically Advanced Scenario.

World oil demand, in the Technologically Advanced Scenario, increases to 4,708 Mtoe (94 mb/d) by 2035, 692 Mtoe (14 mb/d), or 13% lower than in the Reference. The transport sector accounts for more than 80% of the savings. Increased fuel efficiency and accerelated penetration of alternative-fuel vehicles, such as biofuels, or gasoline-powered hybrids etc., are the main factors behind the decreasing in transport oil demand. As illustrated in Figure18, world oil demand consumed in transport sector will peak in 2032 and global oil demand will thereby almost peak around 2035. Natural gas demand is 568 Mtoe, or 13% lower in 2035 than in the Reference. Power sector accounts for most of the savings. Highly efficient technology such as MACC - More Advanced Combined Cycle - is expected to contribute largely to ensure global gas market.

4.3 CO_2 emissions in technologically advanced scenario

Figure19 describes world and Asian CO_2 emissions in both scenarios. In the Technologically Advanced Scenario, the world's CO_2 emissions will increase by 3.4 billion tons or 13% between 2005 and 2020 but will peak in 2026, due to further progress in advanced energy technologies, while CO_2 emissions in Asia will peak in 2030. The policies analysed in the Technologically Advanced Scenario significantly curb the growth of energy-related CO_2 emissions. Lower overall

energy demand and a larger share of less carbon-intensive fuels together yield, in 2035, savings of 12.3 billion tons, or 30%, in emissions compared with the Reference. The reduction is equivalent to around ten times as much as Japan's emissions.

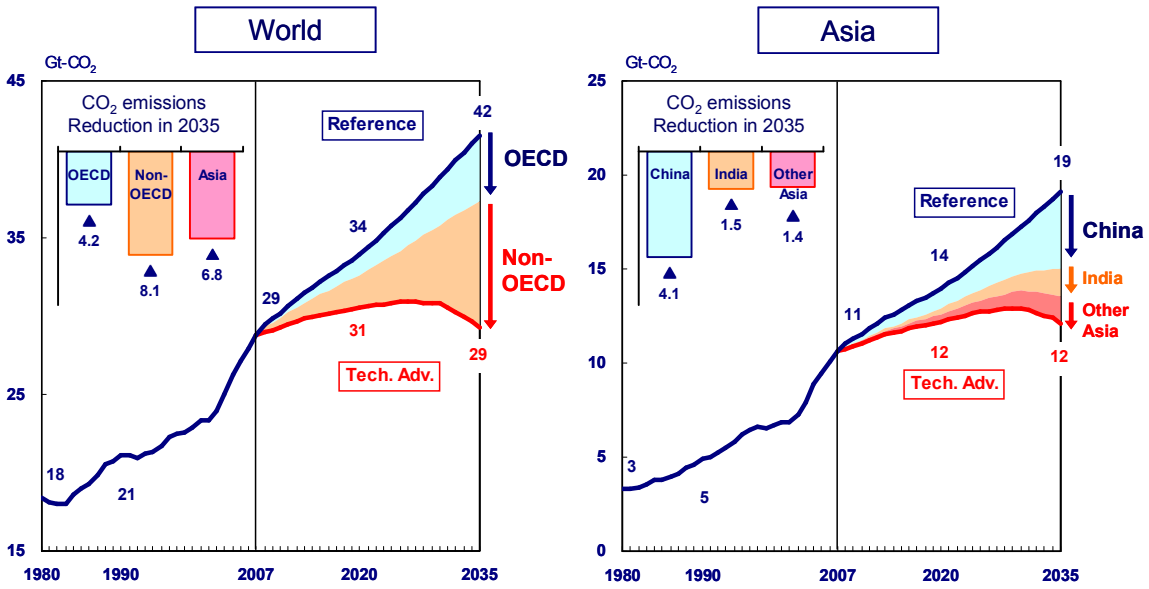


Figure19: CO_2 Emissions in Reference and Technologically Advanced Scenario.

Of the 12.3-billion-ton mitigation, OECD countries will be responsible for 4.2 billion tons and Non-OECD countries 8.1 billion tons. Thus, the CO_2 emissions reduction in Non-OECD countries will be nearly double that of OECD countries. Asia's CO_2 emissions reduction will reach 6.8 billion tons, accounting for 55% of the world's total reduction, indicating Asia's extremely immense potential of CO_2 reduction. CO_2 emissions mitigation in the Technologically Advanced Scenario is greatest in countries that emit the most. Thus, China shows the largest reduction from the Reference to the Technologically Advanced Scenario by 2035, with 4.1 billion tons.

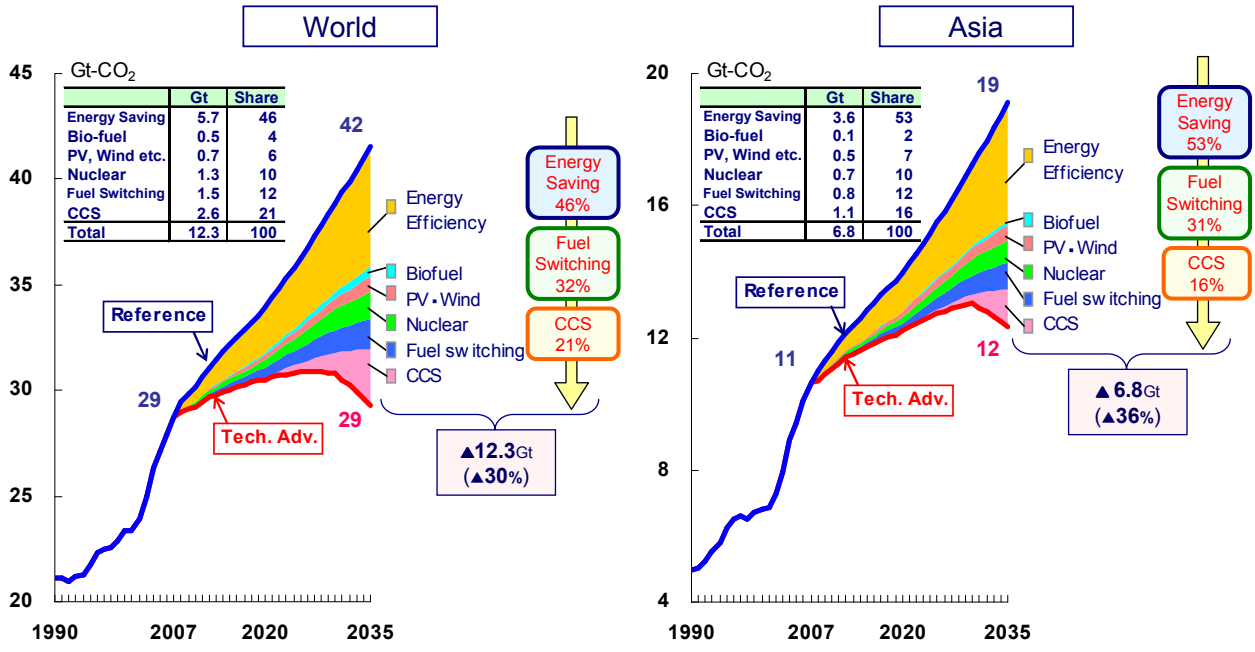


Figure20: CO_2 mitigation by technology in the world and Asia.

The abatement of CO_2 emissions will be a result of combining various advanced technologies, and all technological options are considered to be indispensable. Of the world total CO_2 reduction of 12.3 billion tons in 2035, as illustrated in Figure20, energy efficiency will be responsible for 5.7 billion tons (accounting for 46% of the total reduction), nuclear power 1.3 billion tons (10%), renewable energy 1.2 billion tons (10%), fuel switching 1.5 billion tons (12%) and CCS technologies 2.6 billion tons (21%). Thus, the largest contributor to avoided CO_2 emissions is improved energy efficiency, such as enhanced power generation efficiency and fuel savings achieved through more efficient vehicles and industrial processes, accounting for nearly half of total mitigation. Widespread switching to less carbon-intensive fossil fuels from coal to gas in power generation, increased use of nuclear and renewables in power generation and of biofuels in transport will represent approximately one-thirds of total mitigation. Of Asian total CO_2 reduction of 6.8 billion tons in 2035, energy efficiency will be responsible for 3.6 billion tons (53%), nuclear power 700 million tons (10%), renewable energy 600 million tons (9%), fuel switching 800 million tons (12%) and CCS 1.1 billion tons (16%). Therefore, energy efficiency will play a central role in realizing low-carbon energy system in Asia. Furthermore, the mitigation by energy saving in Asia at 2035, 3.6 billion tons, will contribute to one-third of world total CO_2 reduction. Hence, energy saving in Asia will play a crucial role in reducing a great deal of world CO_2 emissions, which suggests that the transfer of energy efficient technology from developed to developing Asian nations ,and establishing a partnership in energy and environmental area among these nations will be quite influential for realizing global low carbon energy system.

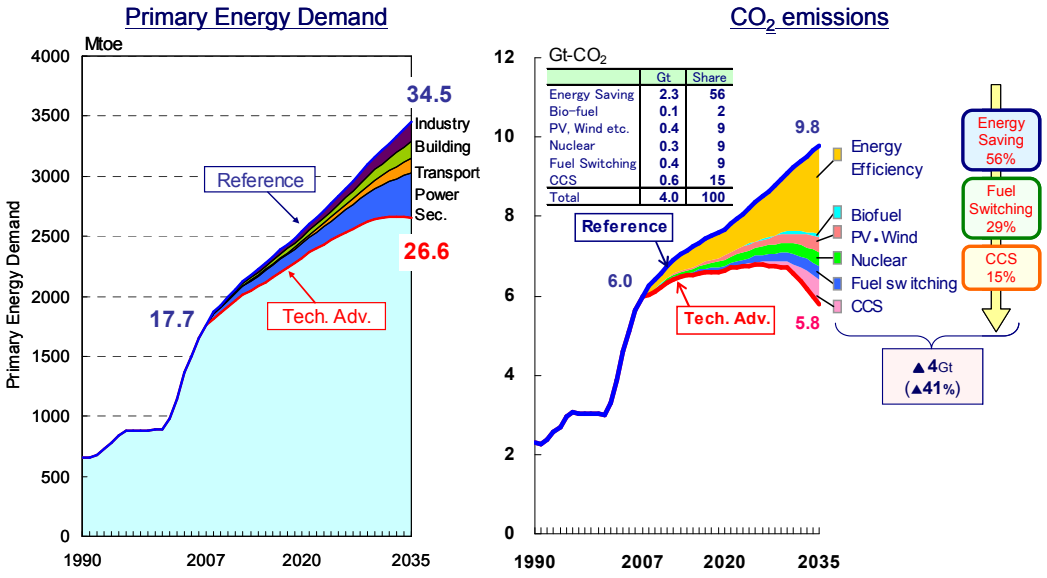


Figure21: Primary energy demand and CO_2 emissions in China.

In the Technologically Advanced Scenario, Chinese primary energy demand will peak in 2033 due to the introduction of advanced technologies as shown in Figure21. In 2035, energy savings of 790 Mtoe, or 23% less, compared to the Reference will be achieved. Power generation sector exhibit a considerable energy demand reduction due to the improved efficiency of coal-fired power plant. Due to this reduction of energy demand and the expanded introduction of nuclear power and other non-fossil energy, CO_2 emissions of China will peak in 2030 without CCS and in 2025 with CCS. In 2035, the Chinese emissions will be reduced by 3.4 billion tons, or 35% less

than in the Reference without CCS (with CCS, 4.0 billion tons, or 41% less).

5 Conclusions

China and the whole Asian region will account for about 30% and 60% respectively of the world incremental growth of CO_2 emissions to 2035. Considering this rapid increase in CO_2 emissions in Asian developing countries, it is obvious that reducing environmental burdens through international transfers of advanced technologies to these countries will contribute to improving energy and environmental issues in the world as well as in Asian region.

In terms of mitigating massive CO_2 emissions in Asia, effective use of fossil fuel is indispensable since fossil energy is dominant energy sources through 2035. Fossil resources are ultimately finite, and their consumption is accompanied by greenhouse gas emissions. Nevertheless, when considering economic rationality, practicality and the lead-time for the commercialization of innovative technologies are considered, it is important to strive toward the effective utilization of fossil resources. Particularly, demand will increase for affordable coal resource for electricity generation in Asian region. In order to prevent global climate change, the development and introduction of high-efficiency coal-fired power generation and clean coal technologies such as CCS are urgently required especially in Asia. Prospecting future remarkable motorization and rising dependence on oil import in Asia, another important challenge will be to tackle for the effective use of oil through the introduction of clean energy vehicles. As non-fossil fuel, nuclear energy will play a major role in Asia, where ensuring energy security will become increasingly important due to fast-growing electricity demand. Nuclear, which is also important for tackling climate change, should be increasingly introduced as a core supply source, along with safety-enhancing technologies. Wind power and photovoltaic power generation are also desirable options among environmental measures. It is necessary to introduce innovation-supporting policies to further expand the use of renewable energy. In Asia to simultaneously achieve its “3E” goals (Energy Security; Environment; Economy), each Asian country should accelerate the decarbonization of energy supplies through diversification of energy supply sources, energy-efficiency and a shift to alternative fuels and strengthen its efforts toward achieving the best energy mix.

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